Armor Material Requirements For US Military Ground Vehicles

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Vector Strategy, Inc.
26 Pinecrest Plaza, #134
Southern Pines, NC 28387
Phone: 910-420-2208
Fax: 910-401-1597
www.vector-strategy.com

VECTOR STRATEGY

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Note: All data tables and graphs present an annual forecast from 2005 to 2020 inclusive.

1 Report Objectives

The purpose of this report is to provide a scenario of material requirements that meets Department of Defense (DOD) annual procurement of armor for military ground vehicles (MGVs). The scenario covers a time horizon of 2005 to 2020.

This report addresses **armor content only** of military ground vehicles purchased by the DOD for deployment by US military services. This report and forecast does not predict material used in the construction of other vehicle components such as hulls, suspensions, engines, weapon system, electronics, etc.

The report is based on anticipated DOD procurement rates of armor for military ground vehicles and Vector Strategy's armor design assumptions. **It is important to note that this report is driven by armor procurement requirements, not annual armor production rates.** This report presents the amount of material required to meet the DOD's annual procurement of armor for military ground vehicles. It does not represent a forecast of materials based on annual armor production. Please see report section 4.0 for a more detailed discussion of this point.

Armor materials addressed in the report include:

- Steel armor plate
- Aluminum armor plate
- Titanium
- Transparent armor
- Ceramic tiles
- Composites and materials used in the construction of composites such as resin, high performance glass fibers, aramid fibers, and UHMWPE uni-directional material.
- Other materials such as depleted uranium and non sensitive energetics for reactive armor.

This report provides a concise supply chain analysis that includes a discussion of industry structure and brief descriptions of supply chain participants.

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3 About Vector Strategy, Inc.

Vector Strategy, Inc. is a private company based in Southern Pines, North Carolina that provides market intelligence for the military armor industry. They help companies stay abreast of technology trends, government procurement, market size and growth, industry players, supply chain issues, and offer other intelligence that business executives need to make informed decisions and build successful strategic plans.

Vector Strategy publishes a set of armor related reports and forecasts throughout the year. In addition, they offer a range of research services that allow us to meet a client's custom needs. Vector Strategy is a member of the Institute for Defense and Government Advancement, the National Defense Industrial Association, and the Association of the US Army.

Forecasts and reports published by Vector Strategy, Inc.:

US Military Ground Vehicle and Armor Procurement Forecast is an analysis and forecast of the US military ground vehicle and armor market. Historical and forecasted vehicle and armor procurement rates from fiscal year 2005 to fiscal year 2020 are presented. Combat wheeled and tracked vehicles, including the Stryker, Abrams, Bradley, and Ground Combat Vehicle, as well as all tactical wheeled vehicles, such as the HMMWV, JLTV, FMTV, MTVR, and MRAP/MATV, are addressed in this report. The forecast includes US Army, US Marine Corps, US Air Force, and US Navy ground vehicle and armor requirements.

This report is essential for business executives responsible for designing, manufacturing, or marketing military ground vehicles or armor for those vehicles. It is also vital for suppliers of vehicle sub-systems and components utilized in the production of armor such as composites, ballistic fabrics, ceramics, metal armor plate, and ballistic transparent glass.

US Military Body Armor Industry: Analysis and Forecast. This groundbreaking report provides a thorough analysis of the US military body armor industry. Forecasted procurement rates of body armor system components for 2000 to 2015 are provided as well as historic, current, and future inventory levels. Material requirements associated with body armor procurement are forecasted, including ballistic fiber and ceramic tile requirements. Technology, political, and military / defense trends affecting the military body armor market are discussed.

The forecast provides full descriptions of major military body armor programs, including history of the armor program, planned and anticipated upgrades, publicly available armor design elements, and a discussion of the industry's supply chain. Company profiles of hard and soft body armor manufacturers and raw material suppliers are included in the report.

4 Report Methodology

4.1 Description of Analysis Technique

Vector Strategy has developed armor design assumptions for approximately 150 different armor solutions and has developed a forecast model that allows for changes in these assumptions on an annual basis from 2005 to 2020. For example, perhaps today a particular armor kit is composed of primarily steel and aluminum; however, by 2020 that kit will consist primarily of ceramic and composite. Vector Strategy's model can reflect this evolution in armor design. The current model is constructed as a relational database in MS ACCESS, which provides more flexibility than the previous model created in MS EXCEL.

There are 25 material choices in Vector Strategy's current armor design model; their previous model offered only 14 different material choices. Current material choices are listed in the figure below.

Material Choices in Vector Strategy's Current Armor Material Requirements Model	
Advanced Transparent Materials	Other Opaque Material
Aluminum	Other Transparent Material
Al Oxide Ceramic	Polycarbonate
Aramid Fiber	Polypropylene Fiber
Depleted Uranium	Resin
Energetic Material	RHA Steel
High Hard Steel	Silicon Carbide Ceramic
High Performance Glass Fiber	Specialty Steel
Other Ceramic	Titanium
Other Fiber	Traditional Transparent Glass
Other Metal	UHMWPE Uni-Directional Material
	Urethane

Figure 1. Material Choices in Vector Strategy's Current Armor Material Requirements Model

Vector Strategy has made a concerted effort to link their armor designs to assumed protection levels for each vehicle platform; at least for kinetic energy threats. They have also developed an armor design or recipe for each kinetic energy protection level, and that protection level dictates the materials chosen within each armor design.

By estimating the surface area of a vehicle that is covered with armor, and using an assumed areal density, Vector Strategy has calculated a total weight for each armor kit. Based on the thickness of each material used within an armor solution and its associated areal density, the percent of total armor kit weight that each material component represents has been calculated.

Armor material requirements are the product of multiplying the percent of total kit weight that each material represents, by total kit weight, by the annual number of kits procured.

A more detailed discussion of armor design assumptions is provided in Section 5.

4.2 Sources of Information

Vector Strategy engages in both primary and secondary research to gather armor market intelligence. Primary research activities include conducting interviews with supply chain participants and military/government staff. Interviews are conducted via telephone or in-person. Vector Strategy also attends major conferences and association meetings related to military ground vehicles and armor.

A multitude of secondary research sources are reviewed on a daily basis to stay abreast of published information relative to the armor industry. These secondary research sources include:

- Company press releases and company websites
- Congressional press releases and testimony regarding vehicle and armor programs
- Government contract awards
- Military and government press releases
- Military program office websites
- Industry trade and news publications
- Industry associations and conferences
- Industry analyst reports
- US Trade and Patent Office activity
- Publications from the Congressional Budget Office (CBO)
- Publications from the White House Office of Management and Budget (OMB)
- Online sources such as www.globalsecurity.org, TankNet Military Forum, and the Federation of American Scientists (FAS) at www.fas.org.
- Online defense news services

Budget documentation that is reviewed specifically to develop anticipated procurement rates of armor kits and armored ground vehicles include:

- US Army base budget documentation released in February of each year.
- USMC base budget documentation released in February of each year.
- US Air Force base budget documentation released in February of each year.
- US Navy base budget documentation released in February of each year.
- Supplemental budgets requested by US Army, USMC, US Navy, and US Air Force.
- Congressional budget action and reprogramming throughout the year.

4.3 Description of Vehicle Categories

Vector Strategy segments military ground vehicles into five different categories. Those categories are:

- Light Tactical Vehicles
- Medium and Heavy Tactical Vehicles
- Other Tactical Vehicles
- Combat Vehicles
- Marine Specific Vehicles

Each category contains vehicle platforms from all military branches whose vehicles fit that description. For example, all HMMWVs, whether procured by the US Army, USMC, USAF, or US Navy, are included in the “Light Tactical Vehicle” category. All medium and heavy tactical vehicles used for logistics and line haul, such as the US Army’s FMTV and the USMC MTVR are included in the “Medium and Heavy Tactical Vehicle” category.

The “Marine Specific Vehicle” category does capture only vehicles procured by the USMC. The word “Marine” is used to describe this category not necessarily because the vehicles are procured by the USMC, but due to the mission of these vehicles. Typically, these vehicles have some degree of swim-ability. It could be argued that the LAV and MPC are similar to a Stryker, and thus should be categorized with the Stryker. However, within this report, the LAV and MPC are defined as a “Marine Specific Vehicle”.

Vehicle programs not covered in this report include the Joint Assault Bridge, Assault Breacher Vehicle, and the Paladin/FAASV. Procurement quantities of these vehicles are limited over the timeframe of this report and thus they did not warrant inclusion or analysis.

The following figure lists every vehicle platform and armor program addressed in this report and the vehicle category in which it belongs.

Vehicle Categories

Light Tactical and Support Vehicles
- HMMWV New Vehicles - All Variants
- Utility HMMWV Recap Program
- Up Armored HMMWV (UAH) Retrofit Program
- HMMWV Modernized Expanded Capacity Vehicle (MECV)
- HMMWV Survivability Improvement Initiative (HSII)
- HMMWV Armor and Frag Kits
- Joint Light Tactical Vehicle (JLTV)

Medium and Heavy Tactical and Support Vehicles
- Light Medium Tactical Vehicles (LMTV)
- Family of Medium Tactical Vehicles (FMTV)
- Family of Heavy Tactical Vehicles (FHTV)
- Medium Tactical Vehicle Replacement (MTVR)
- Logistics Vehicle System Replacement (LVSR)
- Heavy Expanded Mobility Tactical Truck (HEMTT) Truck (New)
- HEMTT-ESP Truck (Recap)
- Palletized Load System (PLS) Truck (New)
- PLS Truck (Recap)
- Heavy Equipment Transporter (HET)
- M915A5 Line Haul Truck
- M916A3 Light Equip Transporter (LET)
- Medium and Heavy Truck Armor Kits
- Next Gen Line Haul Vehicle

Other Tactical Vehicles
- Armored Security Vehicles (ASV)
- RG-31 Mine Protected Vehicle
- Cougar EOD Vehicle
- Medium Mine Protected Vehicle (MMPV)
- Mine Protected Clearance Vehicle (MPCV) Buffalo
- Vehicle Mounted Mine Detector Vehicles (VMMD)
- Mine Resistant Ambush Protected (MRAP) Vehicles
- MRAP All Terrain Vehicle (MATV)
- Armor Kits for ASVs, MPVs, MRAPs, and MATVs
- MRAP Family of Vehicles (FoV) Conversions, Upgrades, Modifications, and Recapitalizations

Combat Vehicles
- Bradley A2 ODS Recapitalization Program
- Bradley A3 Recapitalization Program
- Bradley Reactive Tile Kits (BRAT) and IED Armor Kits
- Bradley Urban Survival Kits (BUSK)
- Bradley Fire Support Team (BFIST) A3 and M7 Vehicles
- Bradley Phase I Field Upgrade Program
- Armored Multi-Purpose Vehicle (AMPV)
- Stryker New Vehicle Procurement
- Stryker Modification Program (SMOD)
- Stryker Double V Hull Program
- M113 A2 to A3 Conversions
- M113 Armor Upgrades and Kits
- HERCULES M88 A2 Conversions and Modifications
- Abrams Frontal and Turret Armor
- Abrams ARAT, TUSK, LAGS
- Abrams M1/M1A1 Upgrade Program
- Abrams M1A2 System Enhancement Program
- Abrams Phase I Field Upgrade Program
- Ground Combat Vehicle (GCV)
- Paladin/FAASV Self-Propelled Howitzer

Marine Specific Vehicles
- Amphibious Combat Vehicle (ACV)
- Assault Amphibious Vehicle (AAV) Upgrades
- Marine Personnel Carrier (MPC)
- Light Armored Vehicle (LAV) Upgrades
- New Light Armored Vehicles (LAVs)
- Internally Transportable Vehicle (ITV)

Figure 2. Description of Vehicle Categories

4.4 Description of Armor Applications

This report segments material use by armor application. That segmentation is based on the following applications and definitions:

Integrated Cab/Hull Armor. This armor is designed as an integral part of the original vehicle. The Stryker's and ASV's bolt-on modular armor are examples of this type of armor, as is the "A" Cab armor of the JLTV and the HMMWV MECV. The A Kit armor for LTAS compliant vehicle programs, such as the FMTV and HEMTT A4, are additional examples of this type of armor.

Integrated IED/Mine Protection. This armor provides IED/mine protection that is integral to the vehicle's hull. I.e. this is the base vehicle's protection against IEDs and mines. Examples of this armor include the Stryker's Double V Hull, and the "A" underbody of the JLTV and HMMWV MECV programs.

Add-On-Armor for IED/Mine Protection. This armor application includes belly kits, wheel well armor, and underbody kits that provide IED/mine protection typically for in-service combat and tactical vehicles. I.e. this is appliqué armor that is added on to the vehicle after it has been placed in service or in theater based on a requirement for IED/mine protection that is greater than the vehicle was originally designed for. It also includes "B" underbody protection kits for the JLTV and HMMWV MECV program.

EFP Kits. These vehicle armor kits are designed specifically to protect against Explosively Formed Penetrators (EFPs) threats. Examples include EFP Kits for the MRAP and the MRAP Expedient Armor Program (MEAP), Frag Kit 6 for the HMMWV, and Stryker Hull Protection Kits.

Small Arms Add-On-Armor Kits. These are add-on-armor kits that typically provide protection against Stanag Level 1 to 3 threats and are installed on tactical vehicles. Examples include LTAS compliant B Kits for FMTVs and HEMTT A4s and B Kits for HMMWVs.

Crew, Location, or Task Specific Add-On-Armor. These armor solutions protect certain locations on the vehicle, or provide protection for specific tasks or crew members. Examples of these armor applications include gunner protection kits, roof armor, cupola's, hatch covers, and blow-off panels.

Spall Liners. This armor application includes composite panels, composite spall liners, metallic floor pans, and ballistic blankets used as spall protection. In this context, composites are defined as fiber-reinforced rigid plastics.

Reactive Armor. These are reactive armor tile kits that contain non sensitive energetics and typically protect against Rocket Propelled Grenades (RPGs).

Abrams Tank Armor. This is heavy tank armor that is similar in design to Chobham tank armor and incorporates the use of depleted uranium. It protects the front, sides, and turret of the Abrams Tank.

5 Summary of Report Assumptions

5.1 Description of the Scenario Upon Which This Report Is Based

Due to the great uncertainty surrounding DOD funding and the US Army's and USMC's vehicle modernization programs, Vector Strategy does not label this report a **forecast** of material requirements for military ground vehicle armor. No one can provide a forecast during these uncertain times. Vector Strategy is providing a **scenario** for future armor material requirements based on a justifiable and rational set of assumptions. Clients are encouraged to carefully study the assumptions used to develop this scenario; these assumptions are discussed in this report section. Vector Strategy will be advising clients of future events which will affect this scenario's assumptions, but clients should also understand the assumptions so they can understand upside and downside risks to the material requirements presented in this report.

This report assumes vehicle and armor procurement rates based on what the US Army and USMC have said they want to accomplish between now and FY20 with some, but not significant, regard to whether enough funding will be available to meet those objectives. This scenario funds JLTV, GCV, and the ACV, for example, but it does not fund these programs to the full procurement rates the US Army and USMC have indicated they would like to have. This scenario does not constrain future average annual funding levels for military ground vehicles to the current level of base budget funding, but it does eliminate supplemental funding for overseas contingency operations over the time horizon of this report.

The annual procurement rates for the US Army's and USMC's vehicle and armor programs upon which this report is based is presented in Appendix A. A summary of procurement highlights is below.

- The HMMWV MECV program (this includes both the US Army requirements and the USMC requirements) initiates with Low Rate Initial Procurement (LRIP) in XXXX and reaches annual procurement quantities of XXXX vehicles by XXXX.
- The JLTV program starts in XXXX and reaches full rate production in XXXX. Maximum procurement rates are XXXX for the US Army and XXX for the USMC.
- Cab B Kits for the JLTV and HMMWV are procured for XX% of new vehicles. This includes XXXX Kits for the JLTV.
- FMTVs continue to be procured through XXXX at a procurement rate of XXXX vehicles a year from XXXX to XXXX.
- New HEMTTs and recapitalized HEMTTs continue through XXXX with a procurement rate of XXX to XXXX a year.
- Investment in the US Army's Tactical Wheeled Vehicle Armor Kit program generates XXXXXX XXXXXX XXX XXX XXXXXXX.
- MTVR and LVSR requirements continue through XXXX upon XXXX XXX XXXXXX XXXXX XXXXXXXX XXX XXX.
- MRAP recapitalizations and upgrades continue through XXXX, XXXXXXX XX X XXX XXX XXX XXXX XXXX XXX XX XXXXX XXX XXXXXXX XXX XXXX XX XXXX.
- ASV procurement XXX XX XXXX for active US Army needs.
- The Abrams M1/M1A1 Upgrade Program XXXX in XXXX at which time the tank production line is kept active with the Abrams Phase I Upgrade Program.
- The Bradley Phase I Upgrade Program is funded with procurement dollars from XXXX to XXXX.

- The AMPV program ramps up in XXXX and continues through XXXX at the rate of XXX vehicles a year.
- Stryker vehicles for a XXX XXXXXXX XXXXXXX XXXXXX XXXX XXXXXand procurement of Mobile Gunned System variants for all SBCTs are procured from XXXX to XXXX.
- Stryker Reactive Armor Tiles Kits (Generation II) are procured in XXXX.
- The Stryker Modernization Program initiates in XXXX and the program includes XXXXX XX X XXXXXX XXXX during the upgrade program for existing vehicles.
- GCV LRIP will begin in XXXX with XX vehicles. Full Rate Production (FRP) will be XXX vehicles starting in XXXX. This scenario XXXX procure any XXXXX XX XXXX for the GCV.
- The AAV will be upgraded with XXXXXXXXXXX XXX XXXXX XXXXXXXXX starting in XXXX. Maximum annual procurement rate will reach XXX vehicles a year. This upgrade will include XXX XXXXXXXXX XXXX XXXXX.
- The LAV will continue to receive XXXXXXXXXX XXXXXXXXXX and this program will include a XXX XXXXXXXXX and X XXX XXXX XXXXX. After ramp-up, XXX vehicles a year will be upgraded within this program.
- The MPC program will begin in XXXX and XXX vehicles a year will be procured. This scenario XXXX procure any XXXXXX XX XXXXX for the MPC.
- The ACV will initiate with LRIP in XXXX with XXX vehicles.

In general, these procurement rates are identical to those reported in Scenario A of Vector Strategy's May 2011 "US Military Ground Vehicle and Armor Procurement Forecast 2020" with some exceptions. Those exceptions are based on procurement or program activity since May 2011 and include:

- Additional XXXX and XXXX procured in June and July 2011.
- All XXXX XXXXXX XXXXXXXXXX kits are procured in 2011; rather than procured over 2011 and 2012 as originally forecasted.
- Added procurement of MRAP XXXXXX XXX Kits in 2011.
- Lowered annual procurement rate of the AMPV to only XXX per year based on future funding uncertainty.
- Moved initial procurement for Stryker Modernization Program from XXXX to XXXX based on future funding uncertainty.
- Assumed that HMMWV MECV B Kits and JLTV B Kits would be procured for XX% of all new vehicles; XXX XXXX XXXXX XXXXX XX XXXX XXXXXXXX.
- Increased the number of LAV Survivability III upgrades from XXX to XXX vehicles per year based on a Request For Information (RFI) released by the USMC in July 2011. The RFI mentioned a procurement quantity of XXX LAVs per year; thus, Vector Strategy's procurement rate of XXX XX XXXX XXXXXXX.
- Added funding for procurement of Abrams Upgrades in XXXX to support that production line; XXX XXXX XXXXXX XXX XXX XXXX XXXX XXXXXXX XXXXXXXX XXXX XXXX.

It is important to note that this report is driven by procurement requirements, not annual production rates.

This report presents the amount of material required to meet the DOD's annual procurement of armor for military ground vehicles. It does not represent a scenario of materials based on annual armor production.

Although it could be arguably better to base a projection on production rates, it is near impossible to do so with any accuracy. There is not enough detailed publicly available data regarding company sales to project the number of specific vehicles or armor kits produced by individual companies.

Thus, Vector Strategy believes the most accurate methodology to determine material requirements related to armor procurement for military ground vehicle is to utilize annual government procurement rates for each armor system and knowledge about the design of each armor system as it can be determined from publicly available sources.

5.2 Important Distinction Regarding Armor Plate Requirements

Armor metal plate (armor grade or commercial grade) that is utilized for a new vehicle's external skin, shell, or hull is not captured in this report. That use of armor plate is defined as fundamental to the vehicle's overall content and essential to vehicle construction regardless of survivability requirements. Armor plate requirements are only captured within this report in the following circumstances:

- When armor plate is a component of a retrofit armor kit (such as HMMWV fragmentation kits, a BRAT kit, or an IED underbelly kit).
- When armor plate is a component of an armor upgrade to an existing vehicle (such as an Abrams armor upgrade during recapitalization of vehicles from M1/M1A1 to M1A2 SEP).
- When armor plate is a component of an integrated armor system applied to a new vehicle (such as Stryker or ASV modular or integrated armor).
- When armor plate is a component of an armor kit applied to a new vehicle on the production line (such as HMMWV A and B kits).
- When armor plate is applied as a supplemental layer or as an additional add-on component to a vehicle's original metal hull, shell, or external skin.

The objective of this report is to project armor material trends and discuss the transition from monocoque metal armor designs to solutions that incorporate multiple metal, ceramic, and composite materials. Including armor plate utilized for a vehicle's external hull or shell would potentially skew the analysis towards an overstatement of metal, at least in the near term. As future military ground vehicles initiate production with all-composite or non-metal hulls, this definition and the underlying assumptions will be readdressed.

5.3 Vehicle Stanag Protection Levels - Assumptions and Trends

As mentioned previously, Vector Strategy has made a concerted effort to link their armor design assumptions to specific protection levels for each vehicle platform; at least for kinetic energy threats. The protection levels outlined in Stanag 4569 have been utilized as the classification system for kinetic energy threats[1]. In addition to that document's identification of protection levels 1, 2, 3, 4, and 5; Vector Strategy has added two hypothetical protections levels to account for common threats not included in Stanag 4569. A summary of Stanag protection levels and Vector Strategy's hypothetical protection levels is presented in Figure 3.

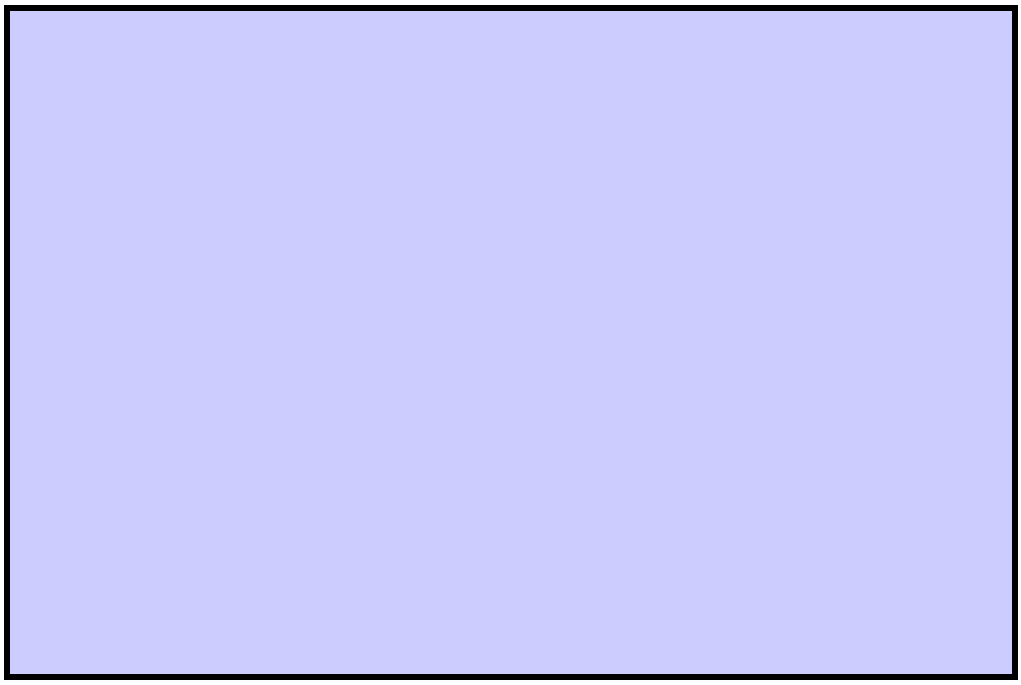

Figure 3. Summary of Stanag Protection Levels

Figure 4 presents Vector Strategy's assumptions for Stanag protection levels for each vehicle category addressed in this report. One will note that this figure is not specific in identifying a single protection level with a particular vehicle platform. Although all assumptions in this report are based on open source data, Vector Strategy believes that assumptions regarding specific vehicle platform protection levels are sensitive information. That information is available to clients and will be provided upon special request.[2]

[1] A January 2004 draft of Stanag 4569 can be downloaded from the Defense Technical Information Center's website and there are multiple other online sources for the document.
[2] The distribution of this additional information is ITAR restricted.

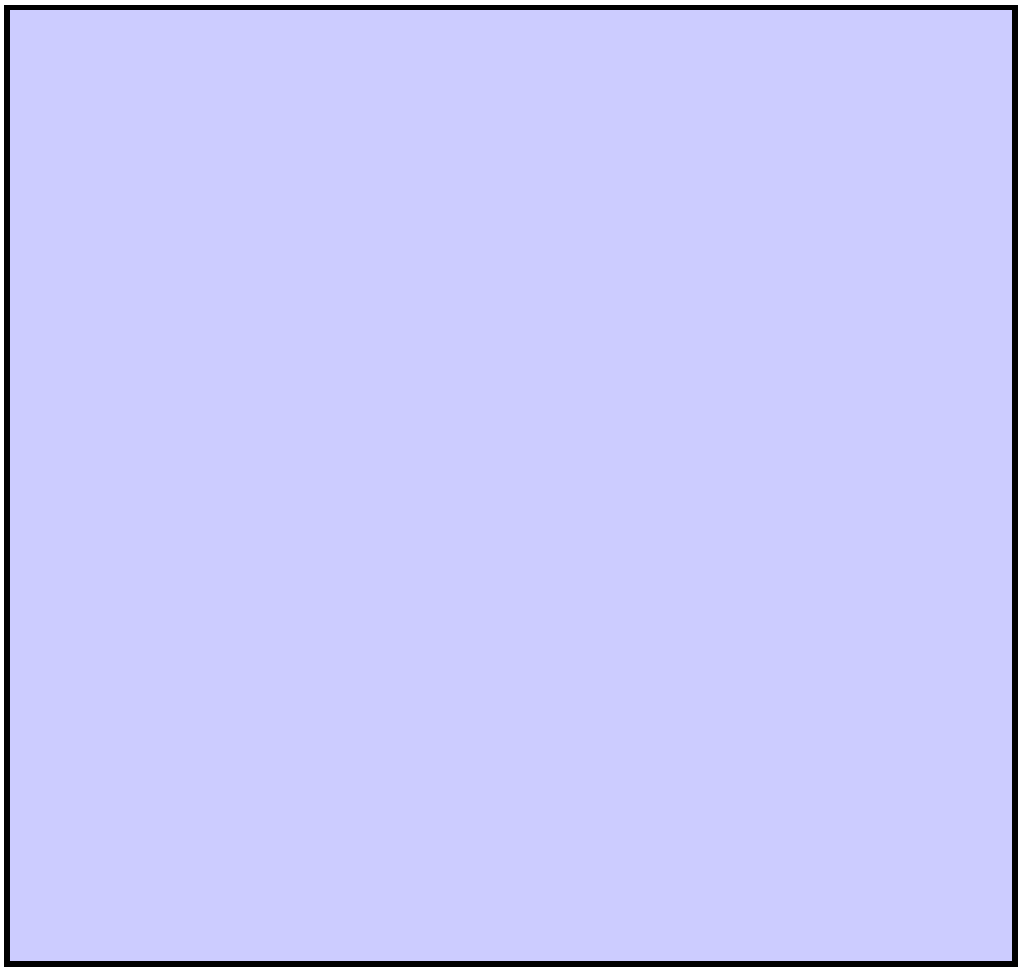

Figure 4. Stanag Protection Level Assumptions By Vehicle Category

As Vector Strategy gathered information on vehicle protection levels and analyzed armor designs over time, a trend of XXXXXX XXXXXXX XXXXX was evident. This trend is illustrated in Figure 5.

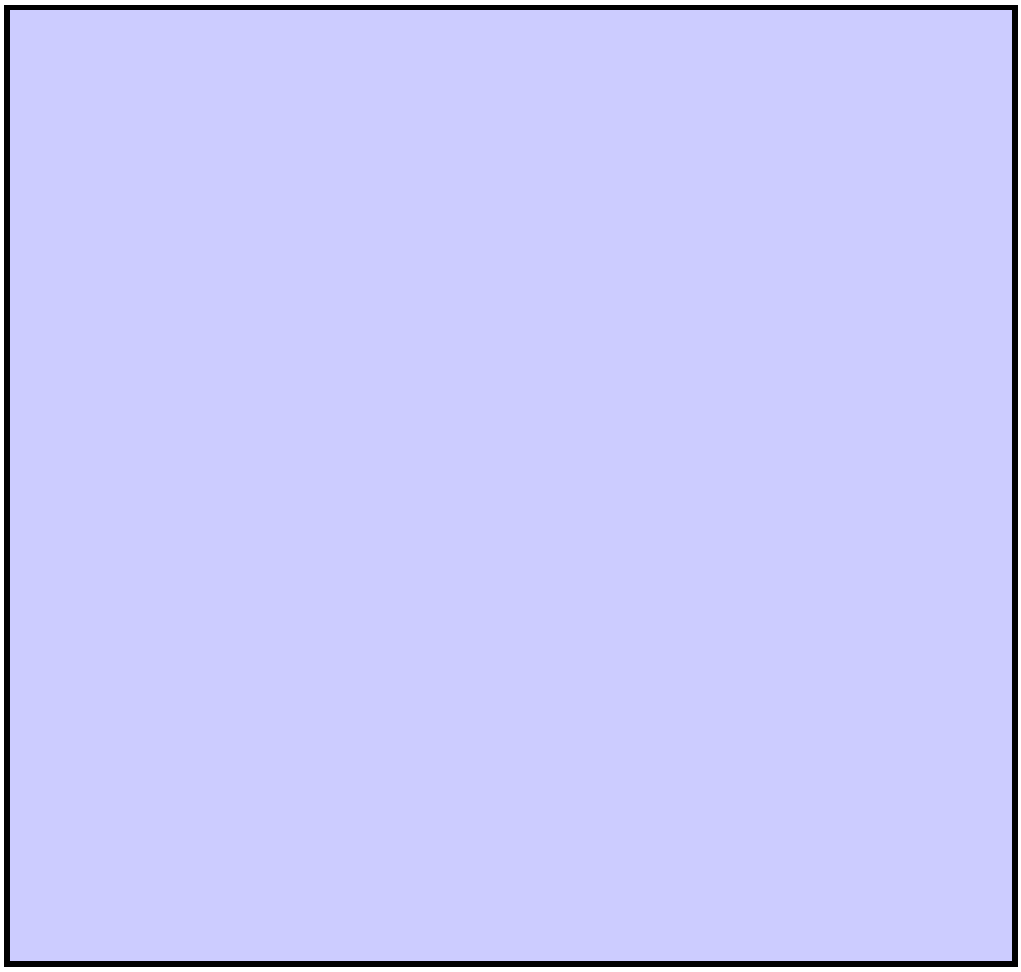

Figure 5. Changes in Kinetic Energy Threat Protection Levels for Military Ground Vehicles Over Time

As Figure 5 illustrates, over time, tactical wheeled vehicles have transitioned from XXXX XXXXX, to XXXXX XXXX XXXX protection levels, to a future that includes XXXXXXXXXXXX armor protection from Stanag protection levels XXX and XXXXX. Mine protected vehicles, a newer subset of tactical wheeled vehicles, is transitioning from XXXXXX solutions to XXXX XXXX XXXXXXXXXX XXXXX. Finally combat vehicles have shifted from Stanag protection level X in the past to a mix of protection level X and X today to perhaps a future of mostly protection level X. Although Figure 5 presents general, non specific trends over time, one can see an overall shift to higher vehicle protection levels.

5.4 Square Foot Coverage of Armor Solutions By Vehicle Platform

As discussed earlier, the total weight of most of Vector Strategy's armor designs is determined by multiplying an areal density by an assumed area of armor coverage on the vehicle. These coverage areas are determined by reviewing photographs of the vehicle and the vehicle dimensions stated by the manufacturer. Upon request, Vector Strategy can provide clients with vehicle platform drawings that identify armor surface area coverage and the associated dimensions of assumed coverage.[3]

Figure 6 provides a list of assumed vehicle coverage for several integrated cab/hull armor protection solutions. In all cases, at a minimum the sides of the vehicle are covered. In most cases, the front and back are also covered, and in some cases the top of the vehicle is covered with the integrated solution. Estimating coverage of integrated armor is not as easy a task as one would assume due to the complex geometry of some vehicle's hulls, angles and slopes incorporated into some hull designs, determining areas that would be armored for crew protection, and determining the armor treatment of wheel wells and track skirt areas. Regardless, it is evident from Figure 6 that as the size (i.e. overall length, width, and height) of the vehicle increases, the amount of vehicle covered with an integrated solution also increases.

Area of coverage for integrated armor ranges from XXX square feet for the MATV to XXX square feet for a Stryker. The area of coverage for GCV integrated armor is based on overall vehicle dimensions assumed by Vector Strategy, as no dimensions are present in the public domain. It is assumed that the GCV will be similar in size to a XXXXXXX. Vector Strategy assumed that the AMPV is a XXXXXXXXXX XXXXXX.

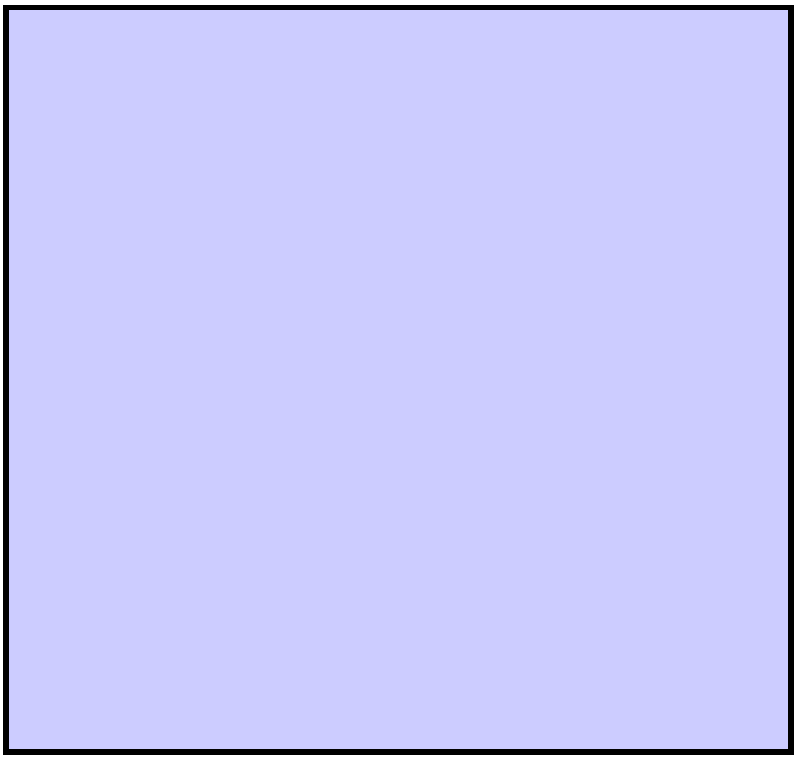

Figure 6. Vehicle Coverage Assumed for Integrated Cab/Hull Armor Protection

[3] The distribution of this additional information is ITAR restricted.

Vector Strategy also needed to estimate the square feet of coverage for all transparent armor applications. In most cases, this was an easier task than that of estimating square foot coverage of integrated armor or add-on-armor kits. Windows can be counted and their size estimated based on other vehicle features. Thus, there is a higher level of confidence in Vector Strategy's transparent armor square foot coverage than in square foot coverage associated with integrated armor solutions.

Only transparent armor solutions for tactical vehicles are listed in Figure 7. There are some armor solutions for combat vehicles that incorporate transparent armor, but these are typically add-on-armor kits with limited transparent armor. These solutions are included in the material requirements presented within this report, but they are not included in Figure 7. Transparent armor coverage ranges from XX square feet for a gunner's protection kit to XX square feet for an MRAP Category III vehicle (i.e. a Buffalo vehicle).

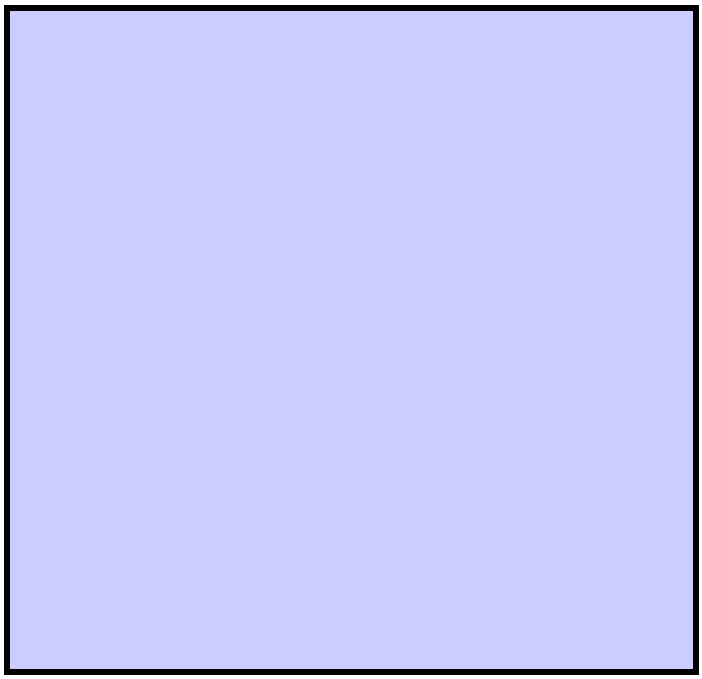

Figure 7. Transparent Armor Square Feet Per Vehicle Assumptions

5.5 Areal Density and Armor Design Assumptions By Stanag Protection Level

Vector Strategy has developed a detailed armor design or recipe for each protection level and a summary of these designs is presented in Figure 8. This figure lists the areal density and generic armor materials used in each design. Upon request, more specific design information will be provided to clients.[4] This would include the specific thickness of each material component and the type of composite, for example.

As one can see from Figure 8, armor designs become more robust as protection levels increase. Vector Strategy's model incorporates two versions of both Level 4 and Level 5+ armor solutions: a standard or baseline solution and an advanced, lighter weight solution. The particular vehicle platform under consideration dictated the choice of which solution was used.

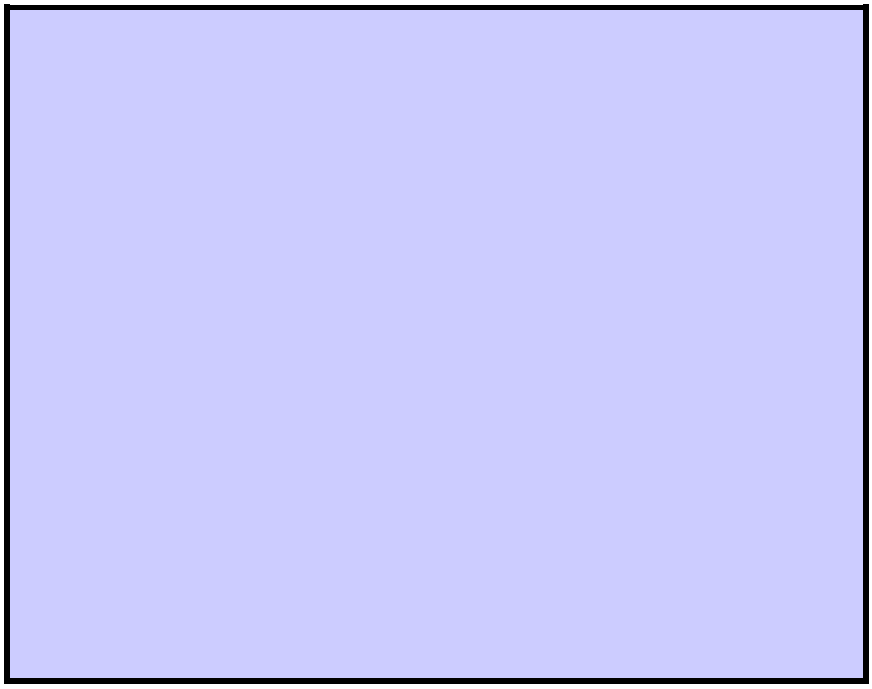

Figure 8. Areal Density and Armor Design Assumptions By Stanag Protection Level

[4] The distribution of this additional information is ITAR restricted.

6 Structure of the Vehicle Armor Industry and Supply Chain Participants

6.1 Overview of Industry Structure

The figure below presents the supply chain for military ground vehicle armor and identifies the major market participants in this supply chain. The figure starts at the top with suppliers of raw materials consumed in the production of armor such as ballistic fiber manufacturers, steel and aluminum plate suppliers, and ceramic powder suppliers. The figure finishes with military stakeholders at the bottom of the diagram.

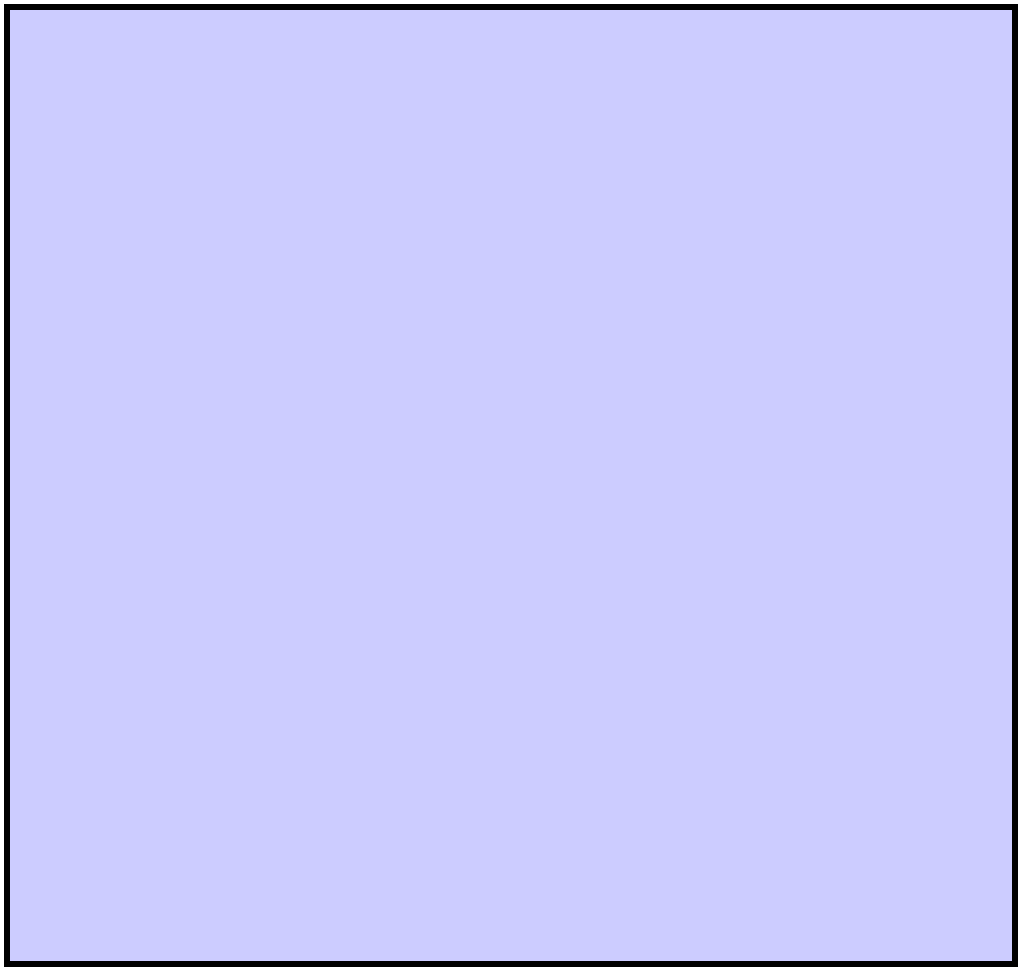

Figure 9. Diagram of the Military Ground Vehicle Armor Supply Chain

This figure is not all inclusive; for example it does not include basic polymer suppliers, metal ores suppliers, or glass and polycarbonate suppliers that are precursors to transparent armor manufacturing. However, the diagram portrays the supply chain participants most important to the armor market.

6.2 Brief Description of Supply Chain Participants

Fiber Manufacturers.

Fabric Weavers. .

Prepreg Manufacturers. .

Composite Manufacturers.

Metal Plate Manufacturers. .

Metal Service Centers. .

Metals Fabricators.

Ceramic Powder Suppliers.

Ceramic Tile Manufacturers. .

Transparent Armor Manufacturers and Resellers. .

Armor Solutions Providers. .

Armor Integration. .

Vehicle Original Equipment Manufacturers (OEMs). .

7 Total Material Requirements

Based on this scenario's assumptions, total armor materials required to meet the DOD's procurement of military ground vehicles is XX million pounds (weight) in 2011. This represents a significant decline from the 2008 peak in armor material requirements of XXX million pounds. 2011 armor material requirements represent only XX% of 2008 armor material requirements. This decline is attributable to significantly lower procurement rates of new vehicles and add-on-armor kits for in-service vehicles. After the market retrenchment of 2012-13, which creates an xxxxxx XXXX XXXXX XX XXXXX requirements, material requirements will reach XX million pounds by 2020; XXX XXXX XXXX XXXXX, XXX XXXXX.

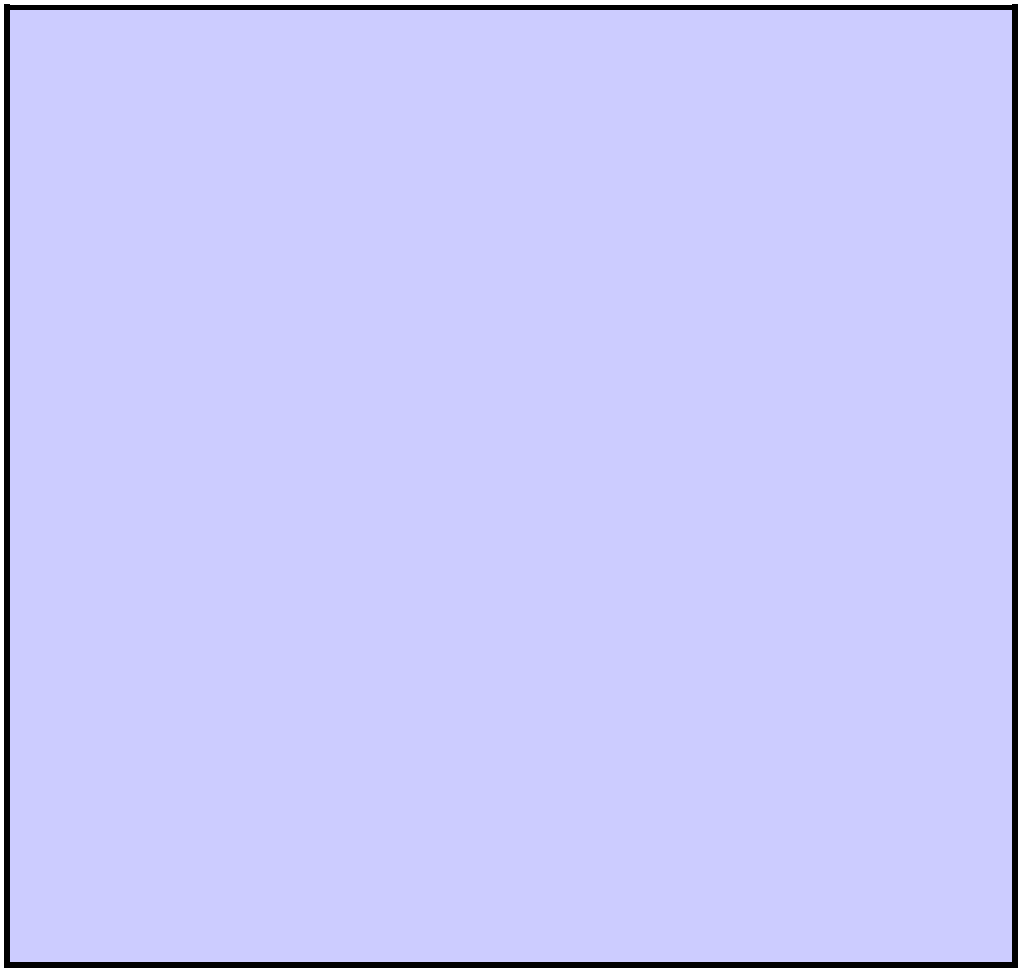

Figure 10. Total Requirements by Material Type - Graph in Millions of Pounds (Weight)

7.1 Total Requirements by Type of Material

Material requirements by type of material are presented in Figure 10 and Figure 11. As one compares current armor material trends to those of 2020, the following conclusions can be made:

- By 2020, ceramic material is XXXXXXX XXXXXXXXXX XXXXXXXXXXXX XXXXXXXXXXX XXXXXXXXXXXXX XXXXXXXXXXXXXXXX XXXXXXXXX.
- Steel use becomes XXXX XXXXXXXX in armor design, for both cab/hull applications as well as underbody protection, and XXXX XXXXXXX XX XXXXX XXXXXXXXX.
- Transparent armor requirements for field replacements XXXXXX XXXXXXXX XX XXXXX XXXXXX XXX XXXXX XXXX XXXXXXX.
- Aluminum's relative share of total armor material requirements XXXXXX XXXXXX as aluminum is XXXXXX XXXXXXX by XXXXXXXXXXXX armor in XXXXX and by XXXX XXX XXXX in XXXXXXXX protection.
- Through the time horizon of this report, the use of titanium XXXX XXX XXXXXX XXXXX XX XXXXXXX XXXXXXX XXX XX XXXX XXXXXXX, XXXX XXXXXXX, XX XXXXXXXX XXXXXXX XXXXX XXXX XX XXXXXX XXXXXXX.

The following paragraphs provide a summary of trends by material type; greater detail is provided in subsequent report sections on each material.

Steel Armor Plate. Steel armor plate represents XX% of 2011 material requirements or XX million pounds. By 2020, steel armor plate will represent XX% of total requirements or XX million pounds. Although steel demand XXX XXX XXXXX XXXXXX from 2011 to 2020, the applications driving that demand XX XXXXXX.

Aluminum Armor Plate. Aluminum armor plate represents XX% of 2011 material requirements or XX million pounds. By 2020, aluminum armor plate will represent XX% of total requirements or XX million pounds. By 2011, aluminum has XXXXX XXXX XXXXX XXXX XXXX XX XXXXXXXXXXX XXX XXX XXXXX XXXXXXXX XXXX XX XX XXXXX, XXX XX XXXXXXXX XX XXXXXXXXX XXXXXXX XXXXX.

Titanium. Titanium represents XX% and XXX XXXX X million pounds of material requirements in both 2011 and 2020. Both years represent a slight anomaly in titanium demand as neither year incorporates procurement of XXXXXXXX XXXXX XXXX XXXX XXX XX XXXXXX XXXXX XXXX XXXX XXXXXXX XXXXXX XXX XXX XXXXXX XXX XXXXXX XXXXXXXXX. Section 10 provides a more in-depth discussion of titanium requirements and armor solutions that incorporate titanium.

Ceramic Materials. Opaque ceramic materials represents XX% of 2011 requirements or XX million pounds. By 2020, opaque ceramic materials will represent XX% of total requirements or XX million pounds. Ceramic materials represent one area of growth in the armor materials market from 2011 to 2020. XXXXXXXXXXX XXXXXX XXXXXX XXXXX XXXXXXXX XXXXX XXXXXXX XXXXXX XXXX XX XXX XXXX XXX XXXXXX XXXX XXX XXXXXXX XXXXXXXXXX XXXX XXXXX XXXXXXX XXXX XXXXXXX XXXXXX XXXXX XXXXXXXXXX XXXXX XXX XXXXX XXXXXXXXXXX XX XXXX XXXXX.

Composites. Composites represent XX% of 2011 requirements or XX million pounds. By 2020, composites will represent XX% of total requirements or XX million pounds. XXXX XXXXX XXXX XXXXX for XXXXXX XXXXXX and XXXX XXXXX for XXX XXXXXXX drives this modest growth.

Transparent Armor. This scenario includes transparent armor requirements for new vehicles, for add-on-armor kits, for recapitalization and upgrade programs, and for field replacements of vehicle windows as required by operational and theater needs. It does not include transparent armor requirements replaced during a vehicle reset activity. By weight, transparent armor represents XX% of 2011 armor material requirements; that corresponds to XXX square feet. By 2020, transparent armor

will represent XXXX XX% by weight of all armor material requirements or XXXX square feet. Although transparent armor requirements XXXXXX XXX XXX XX XXXXXX XXX XXXX, there is a transition to the use of XXXXXXX XXXXXX XXXXXX. This trend and other transparent armor trends are discussed in Section 13.

Other Metals and Other Materials. These categories of materials include two components of armor solutions not included in other report sections. These materials are insensitive energetics used within reactive armor tile kits and depleted uranium used in the Abrams Tank armor solution. These materials represent X% XX XXXX of total material requirements over the horizon of the forecast.

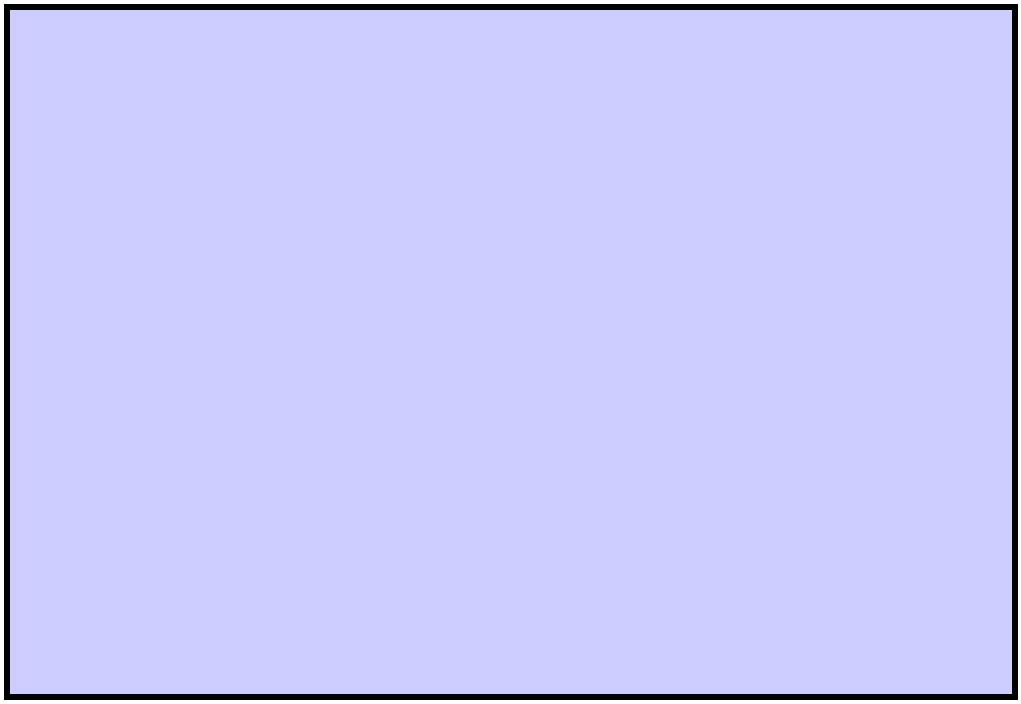

Figure 11. Total Requirements by Type of Material - Data Table in Millions of Pounds (Weight)

7.2 Discussion of Metallic Versus Non-Metallic Armor Solutions and Future Trends

Over the time horizon of this report one can see the effect of the industry's transition from XXXXXX solutions to XXXXXXXXX armor solutions. The materials discussed in this report can be segmented into three categories for this discussion:

- Metals (steel, aluminum, titanium, depleted uranium, and other metals)
- Non-metals (ceramic, composites, and other materials)
- Transparent armor

Note that there may be a metal component to ceramic-composite armor solutions, and thus not all metal is used in a 100% metal armor solution. However, the analysis provided in this report section and the accompanying figures illustrates an overall market trend and is the most judicious method to illustrate this point to report readers.

This analysis shows that metal requirements for the procurement of armor for military ground vehicles XXXXXXXXXXXXX.

As Figure 12 is reviewed, please note the following armor design trends and vehicle platforms that drive a transition to non-metallic armor solutions:

- In 2016 to 2020, XXXXXXXXXXXXXXXXXXXXXXX.
- Integrated hull armor for the XXXX, AMPXXXXV, and the XXXX XXXXXX program contribute to non-metallic demand towards 2020 as these armors are assumed to be ceramic-composite solutions.

XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX XXX XXXXXXX XXX XXXXX XXXXXX

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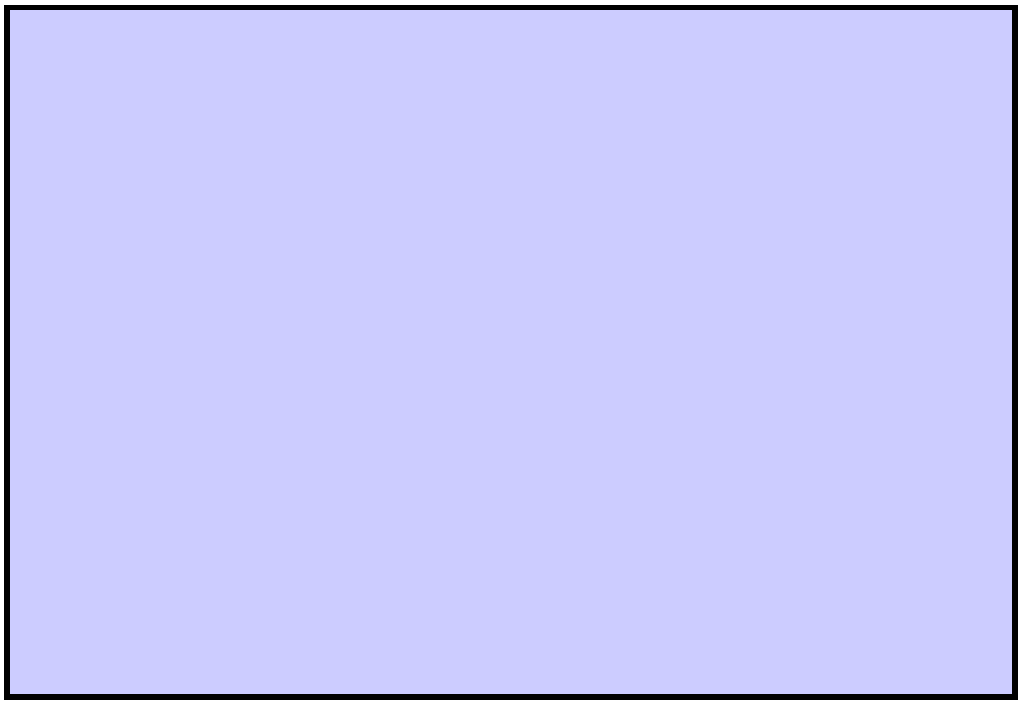

Figure 12. Metallic Versus Non Metallic Content in MGV Armor - Graph

7.3 Armor Material Price Per Pound Trends

Vector Strategy has conducted an extensive analysis of armor material price data twice in the past five years: the first analysis was completed between October 2007 and January 2008; the second analysis was done from May 2011 to July 2011. Each time, DOD awards for armor materials and prices from open sources such as metalprices.com are reviewed. More importantly, Vector Strategy conducts primary research interviews with supply chain participants to confirm armor material price per pound or price per square foot trends.

Figure 13 compares material price data gathered in 2007/2008 with price data gathered in 2011. Overall, material prices have XXXXXXX between XX% and XX% since 2007/2008, with great variability in that price XXXXXX from material to material.

Composite prices have XXXXXX approximately XX%, regardless of which reinforcement is used in the composite. XXXXXXX XXXXXXXXXX XXXXXX XXXXXXX XXX XXXXX XXXX XXXX XXX XXXX XX XX XXX X X X XXXXXX XXX XXXXXX XXXXXXX XXX XXXXX XXXX XXXX XXX XXXX XX XX XXX X X X XXXXXX XXX XXXXXX XXXXXXX XXX XXXXX XXXX XXXX XXX XXXX XX XX XXX X X X XXXXXX XXX.

Of the metals, aluminum pricing seems to have XXXXX. Aluminum pricing has XXXX XXXX XX% since 2007/2008, a much XXXXX XXXXX than steel or titanium. In 2007/2008 the price of High Hard steel was not collected, so only a comparison of RHA prices can be made. Based on data collected, RHA steel pricing has XXXXXX XX% since 2007/2008.

Figure 13 also shows a XXXXX in titanium pricing of XX%. The magnitude of that XXXXX is XXXXXX XXX at XXXX requires explanation. The 2007/2008 price for titanium represents Class 1, Extra Low Interstitial (ELI) grade titanium. In 2011, the price reflects the market's perception of a blended price point that includes ELI, Class 3, and Class 4 titanium as all three types of titanium are utilized for armor.

The analysis of ceramic price changes also deserves explanation. Regarding aluminum oxide, the price per pound has XXXXX XXXXXX from 2007/2008 for 4" by 4" tiles. If one takes into consideration that today, most aluminum oxide ceramic armor is likely comprised of XXXXX XXXX or XXXXX XXXXXX, the 2011 price per pound is closer to $XXX and the price XXXXX relative to aluminum oxide used in 2007/2008 is closer to XX%. It is difficult to compare 2007/2008 to 2011 pricing for silicon carbide ceramic because in 2007/2008 it was assumed that all future requirements would be XXXX XXX silicon carbide and price data was collected only for that type of silicon carbide. Currently, it is assumed that future silicon carbide requirements will be of the XXXXXXX variety and there is no 2007/2008 price data for comparison.

Finally, there has also been price XXXXX in transparent armor square inch pricing. Transparent armor made with traditional glass as a component with an approximate thickness of 2 inches has seen a XX% price XXXX. Traditional technology 4" transparent armor solutions have seen a XX% XXXX. This is intuitive as the 2" solution was a more established product in 2007 and one might expect pricing on that product to have less room to XXXXXX than the 4" solution which was a newer solution in 2007.

All of the price data presented in Figure 13 and discussed above should be viewed as indications of actual pricing and price trends. Although the price data points are based on a considerable number of interviews, the data points should not be viewed as absolute and definitive values. Many factors contribute to material prices: size of award or order, whether the award is made under a blanket purchasing agreement, availability, and lead-time requirements are some examples. A conservative and defendable interpretation of Figure 13 may be that a price change of +/-XX% could be questionable. But price changes of XX%, XX%, and XX% cannot be disputed and are at least indicative of significant price XXXXXXXX for that particular material.

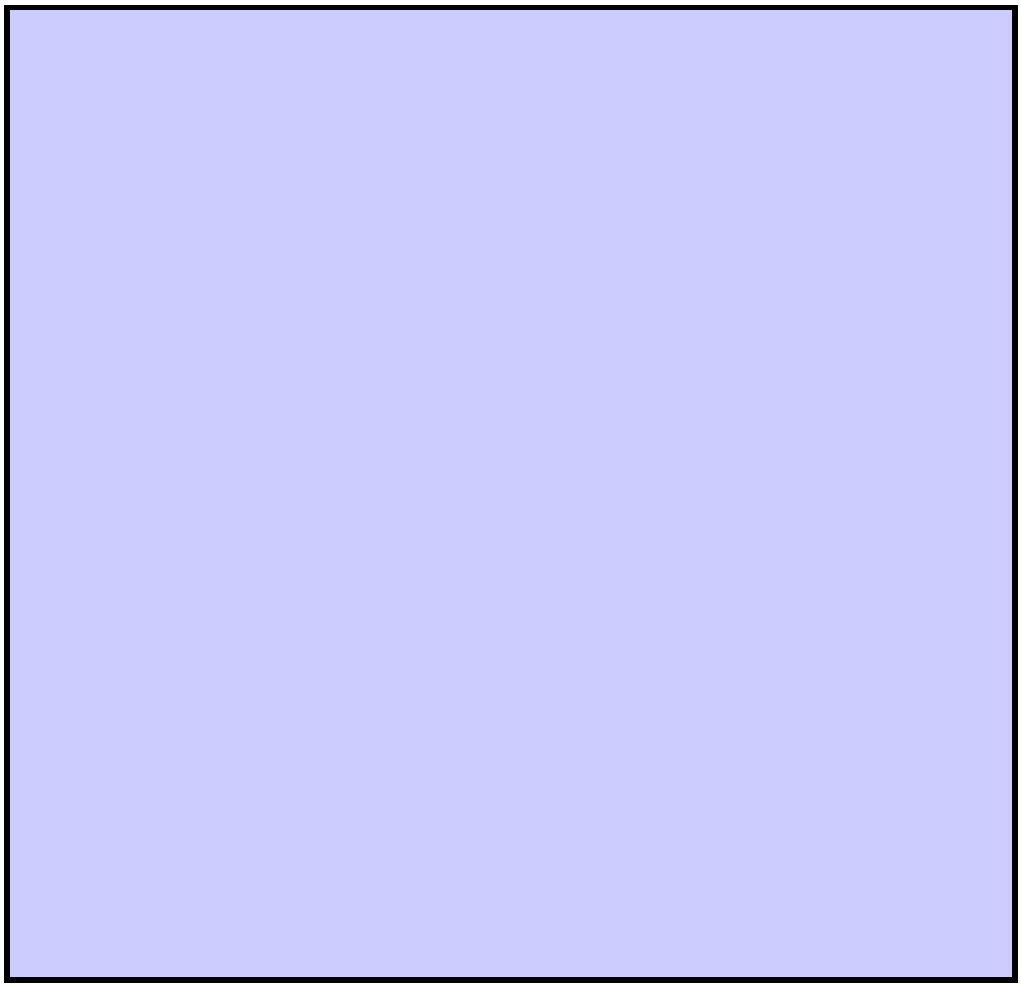

Figure 13. Analysis of Material Price Changes - 2007/2008 to 2011

7.4 Market Value of Materials Used for Military Ground Vehicle Armor

Based on this report's assumptions, 2011 armor material requirements have a market value of $XXX XXXXX. This is a XX% XXXXXX from a peak market value of $XX XXXXX in 2008.

Please note that the market values discussed in the previous paragraph and presented in Figure 14 and in Figure 15 for all years 2005 to 2020 are based on constant 2011 armor material prices. Thus, market value changes due to fluctuations in price per pound are not reflected in annual market values presented in Figure 14 and in Figure 15. As discussed previously, detailed material price information was only collected in 2007/2008 and in 2011. As material price data was not available for other years, it was determined that the best way to present a chart of armor material market values over time was to state all years in terms of constant 2011 prices.

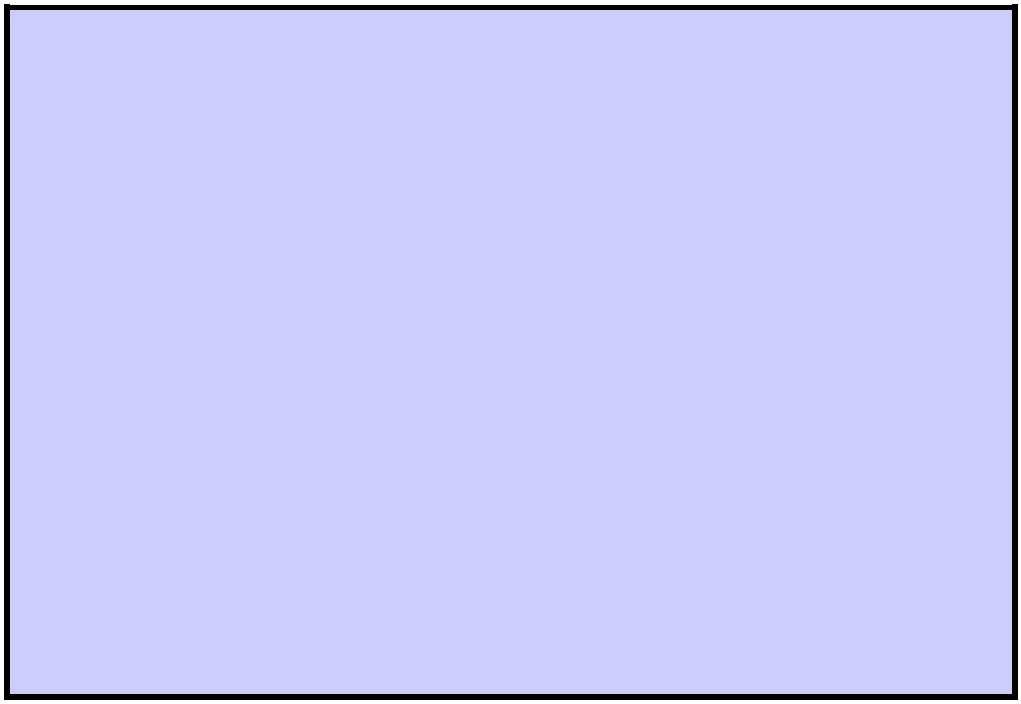

Figure 14. Market Value of Material Requirements for MGV Armor - $ Millions

However, based on the XXXXXXXXXXX XXXXXX in material pricing that was found when comparing 2007/2008 to 2011, it can be concluded that supply chain participants are experiencing not just a XXXXX in market value due to XXXX XXXXXXX, but also a XXXXXX in market value (or sales) due to XXXXXXXXX pricing.

Since two sets of price data are available, a market value variance analysis can be performed to compare the industry's peak market value of 2008 to the market value in 2011, basing both market values on price data for that year. I.e. there is enough price data to generate a 2008 total market value based on 2008 prices and a 2011 market value based on 2011 prices and complete an analysis to determine how much of the 2008 to 2011 decline in market value is due to volume decline versus price decline. The complete calculation and analysis can be found in Appendix C.

The conclusions of that analysis are as follows:

- The overall change in market value, taking into consideration both volume and price, is an XX% XXXXX from 2008 to 2011. This includes all material types: metals, composites, ceramics, and transparent armor.
- The change in overall market value attributable to volume variance or volume XXXXX is a XX% XXXXX.
- The change in overall market value attributable to price variance or price XXXXXXX is a XXXXXXX X%.

Thus, the bottom-line is that both a XXXXXXX volume of material requirements and XXXXXX pricing have created the XXXXXX XXXXXX in overall market value. However, the major contributor has been XXXXXX XXXXXXX.

The market value of each material type is discussed in detail within subsequent report sections and a market value variance for each material is provided in Appendix C, however here is a summary of market value by material type:

- Steel represents XX% or $XX million of total 2011 market value.
- Aluminum represents XX% or $XX million.
- Titanium represents XX% or $XX million.
- Composites represent XX% or $XXX million.
- Opaque ceramic materials represent XX% or $XX million.
- Transparent armor represents XX% or $XXX million of 2011 market value.

A final note on the market value of material requirements: the contribution of a particular material type to the total market varies based on whether that contribution is based on market value or weight. For example:

- Steel only represents XX% of 2011 total material requirements based on market value, but represents XX% of material requirements based on weight.
- Composites represent XX% of the 2011 total requirements based on market value but only XX% based on weight.

